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Final Technical Report

ONR Grant No. N00014-90-J-1916
Analysis of Data From Columbia Point Arena
Ocean-Bottom Seismic Station (OBSS)

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Abstract

This research was the continuation and conclusion of research conducted through FY 89 by G. H. Sutton and others at Rondout Associates, Inc., Stone Ridge, NY and was part of the ULF/VLF ARI to understand the ambient acoustic/seismic noise field in the ocean as a function of location and time in the ULF (0.001 to 1 Hz) and VLF (1 to 50 Hz) frequency band. The objectives of this Grant were to analyze and interpret data from the Columbia-Point Arena ocean bottom seismic station (OBSS); to compare the data with available source information; and to compare the OBSS data with concurrent data from continental arrays.

Introduction

The most extensive existing set of ocean bottom data on ULF/VLF seismic noise and signals was obtained from OBSS, which operated for over six years (1966-1972) about 200 km west of San Francisco at a depth of 3900 m. The OBSS included a Lamont long-period (LP) triaxial seismometer (15 sec natural period, originally developed for lunar use); three-component short-period (SP) system (1 sec natural period); long-period (crystal) hydrophone; short period (coil-magnet) hydrophone; ultralong-period (Vibratron) pressure transducer, thermometer, current amplitude sensor; and a current direction sensor. It was connected to shore via cable and LP and SP components were recorded separately on FM tape as well as on seismograph drum recorders. During this research, original FM tapes from the OBSS long and short period (LP/SP) hydrophones and LP and SP three-component seismometers were digitized to obtain ULF/VLF spectra and covariances during quiet and noisy times and during passage of vessels and earthquake wavetrains. These were compared with available source information on sea/swell condition, tidal currents, earthquakes and shipping and with data from continental arrays. Analyses were conducted in the frequency band 0.002 to 5 Hz.

The continental arrays (ALPA, LASA, and NORSAR) were in operation only during the last two years of OBSS operation. For this reason under this Grant, we concentrated on that time period, obtaining samples of special interest based on weather maps and the original photographic records

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from OBSS. We coordinated our data search with another CNR contractor (Teledyne) who was analyzing the array data. We found little correlation between the two data sets; almost certainly partly due to different analysis procedures. Although we believe there are real and interesting differences between the oceanic and the continental data, we were unable to obtain a publishable set of comparisons in the time period of the Grant.

During the data retrieval and digitizing, we discovered that a crystal pressure gauge had been installed in shallow water near Point Arena and its signals had been recorded on one of the long-period tape channels during October-November, 1970. This data provides a direct comparison between ocean swell near the California coast and microseisms recorded at the OBSS, 100 mi. offshore.

Of the publications listed below, three result from analysis of OBSS data; the McCreery *et al.* paper discusses results from the Wake Island hydrophone array. The following preliminary draft is the only OBSS paper utilizing the near-shore swell data. We believe we have reduced enough additional OBSS/swell data for another publishable paper. In addition, a great deal more OBSS data remains at Lamont Observatory unanalyzed.

OCEAN BOTTOM MICROSEISMS FROM A DISTANT SUPERTYPHOON (DRAFT)

Abstract (Draft)

Haubrich, Munk and Snodgrass (1963) (HMS) described the swell and related microseisms recorded (on land) near San Diego, CA resulting from an intense distant storm in the Ross Sea. In this paper we describe a similar data set produced by a supertypphoon in the western Pacific, near the Philippine Islands, and recorded from an ocean-bottom seismic 'station' (OBSS) located about 200 km west of San Francisco at a depth of about 4 km. In both cases the microseisms are generated in the vicinity of the station and narrow-band spectral peaks are observed with frequency increasing slowly with time from the ocean-wave dispersion.

Introduction (Draft)

A narrow spectral peak was observed on data from between October 18 and 22, 1970, from a pressure gauge installed in shallow water near Point Arena, CA (38° 56.8' N, 123° 45.4' W). Over a period of 98 hours, the frequency increased linearly from 41 to 65 mHz (a period decrease from 24.4 to 15.4 sec). Assuming that the observed swell was generated at a single source location and time and that the swell traveled at the deep-water group velocity, $g/2\pi f$, a distance and origin time can be obtained for the hypothetical source.

Concurrent with the swell arrivals, narrow spectral peaks at twice the frequency occur on the OBSS, located at 38° 09.2' N, 124° 54.4' W, in a water depth of 3903 m, about 134 km from Point Arena. These observations are

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similar to those of HMS who, however, recorded the microseisms at a continental station near the coast (San Diego, CA).

Data and Results (Draft)

Figure 1 shows the track of supertyphoon Joan, between October 10 and 17, 1970, that we correlate with the source of the observed ocean swell and microseisms. The least square fit of swell frequency vs. arrival time at OBSS is shown in Figure 2. This results in a calculated distance of 10,750 km and origin time of 153 hrs before 0000 Z 10/18 for a discrete point source. This source is indicated as S on the storm track in Figure 1. The duration, size and movement of the actual storm produce some ambiguity in this result.

A two-to-one frequency relationship between the supertyphoon swell and microseisms is clearly illustrated in Figure 3. We note, however, that the broad principal swell and microseism peaks are not accurately two-to-one in frequency. This is probably related to the complicated interactions among several independent, distributed sources.

An example of spectra from pressure and all three motion components at the OBSS is shown in Figure 4. (The horizontal components are oriented parallel and perpendicular to the depth contours and coastline: positive at 156° and at 246° azimuth, respectively.) We note that the peak from the supertyphoon is small compared to the main peak. HMS observed single frequency microseisms (equal to the swell frequency) at levels 20 to 40 dB below the double-frequency peak. Although we should have observed such levels on the pressure and vertical sensors (but probably not on the horizontal) no single frequency microseisms were observed on the OBSS from this storm.

The phase difference between the vertical and horizontal motion perpendicular to the depth contours for two different time intervals is shown in Figure 5. The upper plot, from Sutton and Barstow (1990), shows a constant $+90^\circ$ phase between about 0.06 and 0.17 Hz. From comparison of amplitude and phase relationships among pressure and horizontal and vertical motion with those expected from theoretical velocity-depth models, Sutton and Barstow interpret these arrivals to be fundamental mode Rayleigh waves, with prograde particle motion, propagating toward the coast. Using the same interpretations, we see, from the lower plot, the same relationship for the broad main microseism peak but propagation away from the coast (-90° phase) for the microseisms near 0.1 Hz generated by swell from the super-typhoon. In this case the Rayleigh wave microseisms are generated shore-ward of OBSS.

Publications Directly Related to and Resulting from This Grant

Barstow, N., G. H. Sutton, and J. A. Carter, 1989. Particle Motion and Pressure Relationships of Ocean Bottom Noise: 3900 m Depth; 0.003 to 5 Hz, *Geophysical Research Letters*, **16**, 1185-1188.

- McCreary, C. S., F. K. Duennebeir, and G. H. Sutton, 1993. Correlation of Deep Ocean Noise (0.4 - 30 Hz) with wind, and the Holu Spectrum — A World Wide Constant, *J. Acoust. Soc. Am.*, **93**, 2639-2648.
- Sutton, G. H. and N. Barstow, 1990. Ocean-bottom ultra low-frequency (ULF) Seismo-acoustic Ambient Noise: 0.002 to 0.4 Hz, *J. Acoust. Soc. Am.*, **87**, 2005-2012.
- Sutton, G. H. and N. Barstow. Ocean Bottom Microseisms from a Distant Supertyphoon, to be submitted to *Geophysical Research Letters*.

Figure Captions

- Figure 1. Tracks of cyclone centers near Philippine Islands in October 1970 including that of supertyphoon Joan: A – typhoon force winds, 0500 Z 10/11; B – supertyphoon force winds, 1100 Z 10/12; C – maximum (150 K) winds, 0000 Z 10/13; S – location of storm center at calculated origin time of observed swell, 1500 Z 10/11. Open circles indicate 1200 Z and closed circles 0000 Z.
- Figure 2. Least-square fit of peak frequency of storm swell recorded near Pt. Arena, CA as a function of time in hours from 0000 Z 18 October, 1970.
- Figure 3. Power spectra from swell recorder, S, near Pt. Arena, CA and OBSS long-period hydrophone, P, showing spectral peaks associated with swell from supertyphoon Joan. Short vertical lines identifying the peak frequencies are a factor of 2.0 apart; maxima of main microseisms are about 1.7 apart. P spectra are Pa^2/Hz ; S spectra are proportional to pressure, i.e., dB level is arbitrary but shape is not: top – 2000 - 2200 Z 19 October, 1970; bottom – 0200 - 0400 Z 21 October, 1970. (Spurious spectral line at 0.09 Hz is blanked out.)
- Figure 4. Power spectra from OBSS long-period hydrophone and seismometers (2000 - 2200 Z 19 October, 1970) showing spectral peak at 0.104 Hz generated by swell from supertyphoon Joan. Spectra for $H_{||}$ and H_{\perp} (horizontal) are raised relative to Z (vertical) by 10 and 20 dB, respectively. Velocity scale on left and pressure (P) scale on right. (Spurious spectral line at 0.09 Hz is blanked out.)
- Figure 5. Spectral phase difference between vertical and horizontal seismic motion perpendicular to bathymetric contours (H_{\perp}) near OBSS: top – microseisms associated with a storm in N. E. Pacific (1300 - 1500 Z 7 December, 1967, see Sutton and Barstow, 1990, Figure 9); bottom – during swell storm (2000 - 2200 Z 19 October, 1970). Note 180-degree phase shift near 0.1 Hz indicating opposite direction of propagation, assuming same propagation mode.

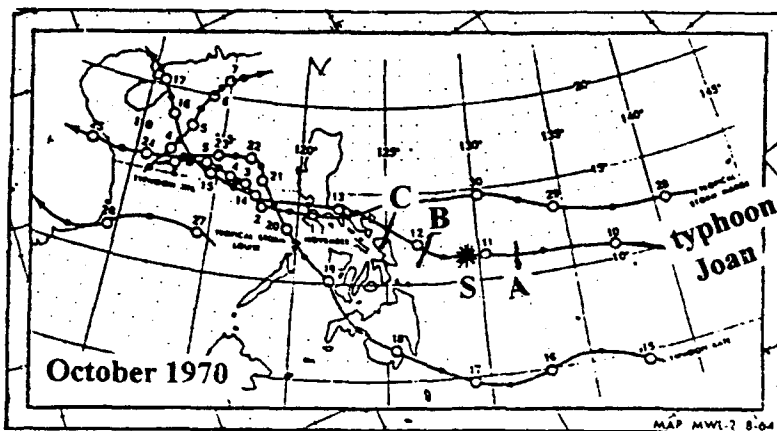
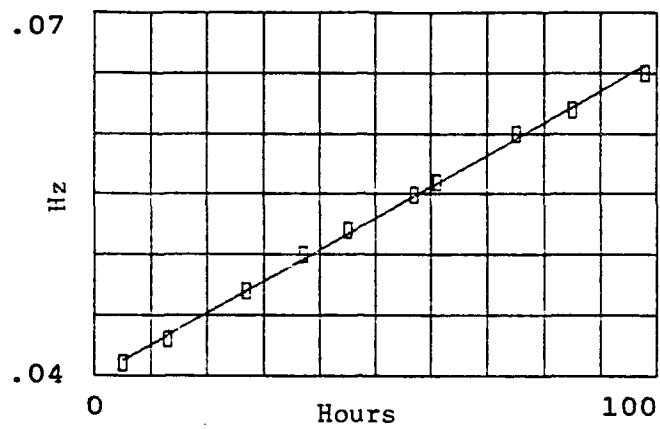


Fig 1



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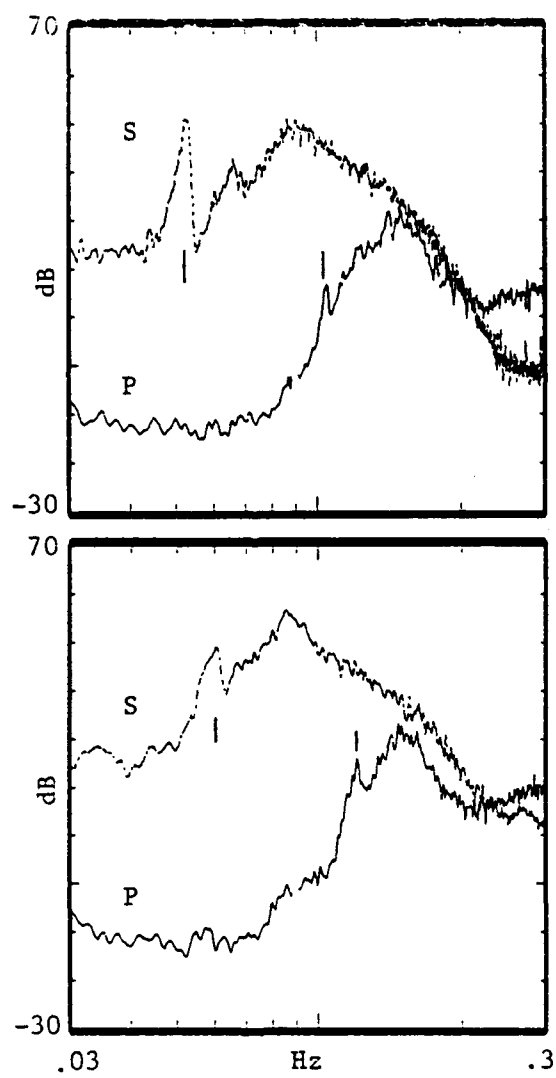


Fig 3

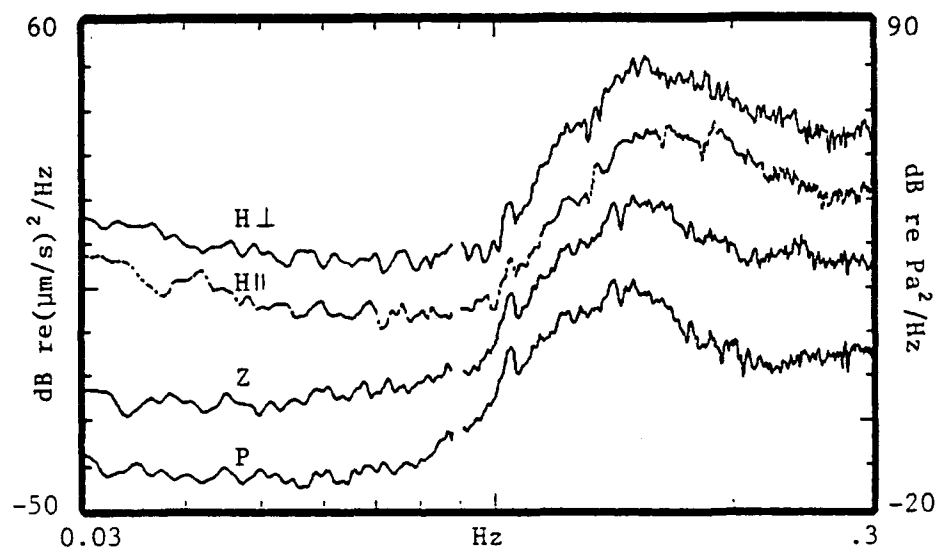


Fig. 4

